

## Efficacy of *Nephaspis amnicola*<sup>1</sup> and *Encarsia ?haitiensis*<sup>2</sup> in Controlling *Aleurodicus dispersus*<sup>3</sup> in Hawaii<sup>4</sup>

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### ABSTRACT

The introduction and establishment of *Nephaspis amnicola* and *Encarsia ?haitiensis* have resulted in successful biological control of *Aleurodicus dispersus* in lowland and highland Honolulu. *N. amnicola* was more effective in reducing high whitefly populations and *E. ?haitiensis* was more effective in low whitefly populations. The peak population densities of *A. dispersus* were reduced by 79.0% from 1980 through 1981 in lowland Honolulu, and by 98.8% from 1980 through 1981 in highland Honolulu. In addition, rainfall and temperature may have played an important role in regulating the whitefly populations, and previously established predators may have also contributed in reducing high whitefly populations.

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*Aleurodicus dispersus* Russell, a pest of vegetables, fruit trees, ornamentals and shade trees, was discovered in the city of Honolulu on the island of Oahu in Hawaii in September 1978. It dispersed rapidly throughout Oahu and by August 1981 it became established on the islands of Kauai, Maui, Molokai, Lanai and Hawaii. *A. dispersus* is known to occur in southern Florida, Central and South America, West Indies, and the Canary Islands (Russell 1965). In 1981, it was found in American Samoa (Lai, Per. Comm.) and Guam (Nechols, Per. Comm.). In Hawaii, *A. dispersus* is commonly called the spiraling whitefly (SWF) because of its spiral egg-laying pattern. In Florida, it is known as the Keys whitefly (Tri-ology 1981).

Although nymphs and adults feed by sucking on the sap of leaves, injury was usually insufficient to kill plants even under heavy infestations. However, copious amounts of white flocculence secreted by the nymphs created not only an intolerable nuisance when dispersed by the wind but also an unsightly appearance to the plants. In addition, the sticky honeydew served as a substrate for the growth of sooty mold which interfered with photosynthesis. The problem was further escalated by its extensive host range of over 100 plant species, of which guava, banana, plumeria, mango, sea grape, and tropical almond appeared to be the most preferred (Nakahara 1978).

Because of the initial widespread infestations and rapid rate of dispersal of the SWF, eradication was not attempted. Instead a biological control program was initiated by the Hawaii Department of Agriculture. A search for natural enemies was conducted by an exploratory entomologist in April 1979 and again in January 1980 in tropical America. Three species of coccinellids and two species of aphelinids were subsequently introduced, studied for host-specificity, successfully propagated, and distributed throughout the State. Of these introduced natural enemies, *Nephaspis amnicola* Wingo and *Encarsia ?haitiensis* Dozier were the more successful species

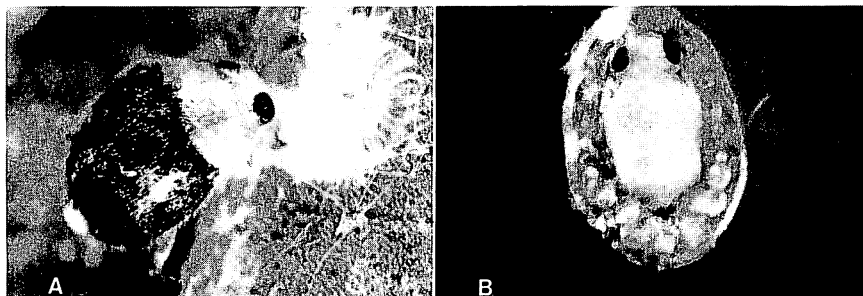
<sup>1</sup>Coleoptera: Coccinellidae.

<sup>2</sup>Hymenoptera: Aphelinidae.

<sup>3</sup>Homoptera: Aleyrodidae.

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**FIGURE 1.** A. *Nephaspis amnicola* (♂) feeding on *Aleurodicus dispersus*; B. Pupa of *Encarsia ?haitiensis* developing in *A. dispersus* (in alcohol).

(Fig. 1). *N. amnicola* was introduced from Honduras and Trinidad, West Indies, and *E. ?haitiensis* was introduced from Trinidad. The objective of this study is to evaluate the effectiveness of these two species.

### MATERIALS AND METHODS

The study was conducted in 2 areas with different climatic conditions in Honolulu from May 1980 to December 1981. The areas were designated and characterized during the 20-month study as follows: (1) "lowland Honolulu": elevation, 3.1 - 15.2 m; average temperature, 25.7°C; and total rainfall, 124.8 cm; and (2) "highland Honolulu": elevation, 118.9 - 131.1 m; average temperature, 23.2°C; and total rainfall, 321.9 cm. The average temperature and rainfall from these 2 areas were significantly different ( $t = 6.68$ , d.f. = 38;  $t = 5.24$ , d.f. = 38, respectively). The climatological data used in this study were obtained from the National Oceanic and Atmospheric Administration (1980-1981).

A total of 205 *N. amnicola* adults was released in the lowland Honolulu site during December 1979 to March 1980 before the study was initiated. *N. amnicola* was not released in the highland Honolulu site. *E. ?haitiensis* was not released in either of the areas. Three guava trees (*Psidium guajava* L.) were selected for monthly samplings within each of the 2 areas. From each tree, 10 leaves (average size =  $415.7 \pm 182.0$  cm<sup>2</sup>) were randomly selected and carefully placed into a labeled plastic bag (15.5 × 39.5 cm).

The relative population densities were determined by counting pupae of the SWF, pupae of parasites, and larvae, pupae and adults of predators. To facilitate counting of SWF and parasite pupae, the cottony debris and predators were carefully brushed off into each sample's plastic bag before transferring the leaves. The leaves were held for parasite emergence in a gallon jar covered with organdy (White Rose) and secured with rubber bands.

All predators that were brushed into the bag were killed in a .3% dishwashing detergent solution, separated from the liquid with a fine sieve (.09 mm), and transferred to a 100 ml holding jar containing 70% ethyl alcohol for subsequent identification and enumeration.

Data of temperature, rainfall, and the average number per 10 leaf-samples were treated with  $\sqrt{x + 1}$  transformation, and correlation and regression were then determined.

## RESULTS AND DISCUSSION

Figs. 2 and 3 illustrate the population trends and interactions among the SWF, *N. amnicola*, and *E. ?haitiensis* in the leaf-samples collected from lowland and highland Honolulu. Average monthly temperatures and total monthly rainfall are also presented. Table 1 summarizes the correlation and regression of the relationships between the whitefly and its natural enemies, and between the whitefly and temperature and rainfall.

*Lowland Honolulu*

Fig. 2 shows that the density of the SWF was at a peak of 461.3 pupae when the study was initiated in May 1980. In the following months, the population steadily declined until it reached 4.0 in November. During the next 3 months, the population remained at a low level. In March 1981, the population began to increase, with a slight decrease in May to 53.7 pupae before attaining a peak of 96.7 pupae in June. Thereafter, the population declined to 12.3 pupae in September. In October, the density increased to 25.0 pupae and declined to 6.0 pupae in the following two months. A comparison of the two peaks in 1980 and 1981 revealed that the number of SWF pupae declined by 79.0%.

*N. amnicola* was recovered in the first month of the survey and its density reached a peak of 24.3 individuals in June 1980, 6 months after its first release. At this time, the density of the SWF was 409.3 pupae. Subsequently, the population of *N. amnicola* gradually subsided as the SWF population diminished. Throughout 1981, *N. amnicola* remained at a very low level, never exceeding 1.3 individuals although there was a slight increase in the SWF population. The results indicate that there was a significant, positive correlation between the predator and the SWF ( $r = 0.58$ ,  $t = 3.03$ ).

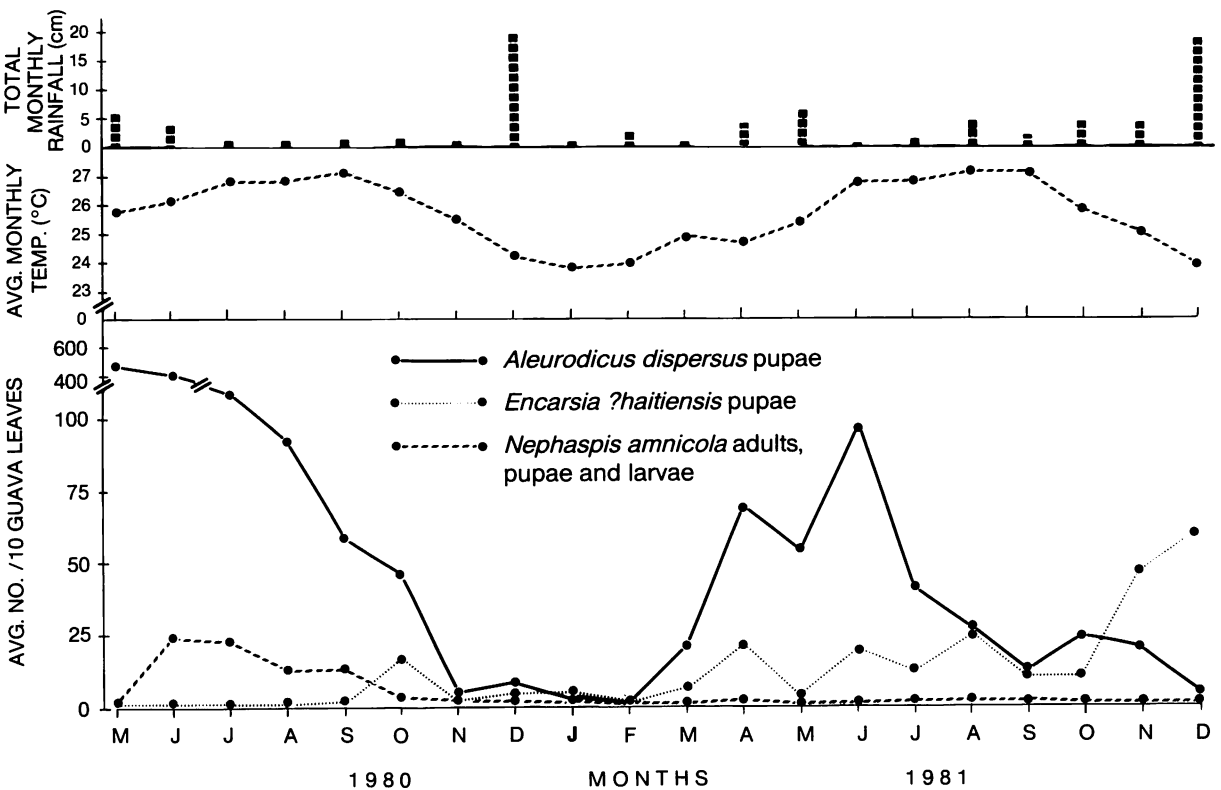
*N. amnicola* was the predominant natural enemy responsible for the reduction of the SWF population in 1980. The predator was more abundant during 1980 than in 1981, ( $t = 2.36$ , d.f. = 18,  $P < 0.05$ ) probably because higher host densities in 1980 favored the actions of the predator (van den Bosch et al. 1959). The predator usually remained in high host density areas with limited dispersal until the decline of the host.

*E. ?haitiensis* was first recovered in the fifth month of the survey, increased in density to a peak of 16.3 pupae in October 1980, and then decreased to 2.7 pupae in the following month as the SWF population subsided. In March 1981, parasite density increased as the SWF population began to increase, and thereafter, fluctuated with the SWF population through October. During November and December 1981, however, there was a substantial increase in parasite density to 61.3 pupae with a corresponding decline in the SWF population. There was no significant correlation between the parasite and the SWF ( $r = 0.12$ ,  $t = .42$ ).

The parasite was less abundant during 1980 than in 1981 ( $t = 2.49$ , d.f. = 14,  $P < 0.05$ ). Since the parasite was not released in the site, additional time may have been required for the parasite to become established. By March 1981, the parasite had become established as a predominant natural enemy. Unlike *N. amnicola*, *E. ?haitiensis* appeared to perform well even at the decline of the SWF during August and December 1981. The superior performance of the parasite over the predator when the SWF population is low may be attributable to either a lower food requirement or a higher searching ability of the former allowing the parasite to thrive at lower host densities (Doutt and DeBach 1964).

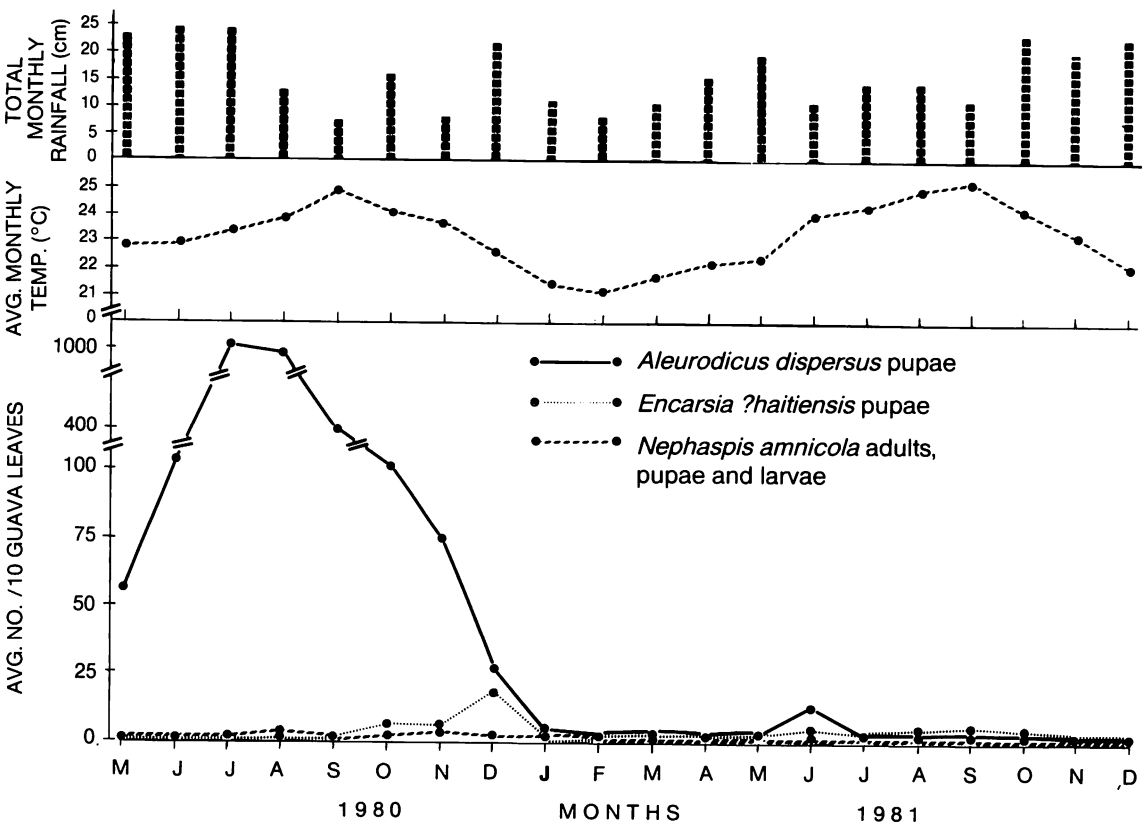
The average monthly temperatures generally followed a cyclic pattern throughout the study. Temperature was highest during September 1980 and 1981 and lowest during January 1981. As shown in Fig. 2, the SWF population fluctuated with temperature. Significant, positive correlation was obtained between temperature and

## LOWLAND HONOLULU



**FIGURE 2.** Control of *Aleurodicus dispersus* in lowland Honolulu by *Nephaspis amnicola* and *Encarsia thaitiensis* with average monthly temperature and total monthly rainfall during May 1980 to December 1981.

## HIGHLAND HONOLULU

**FIGURE 3.**

Control of *Aleurodicus dispersus* in highland Honolulu by *Nephaspis amnicola* and *Encarsia ?haitiensis* with average monthly temperature and total monthly rainfall during May 1980 to December 1981.

SWF abundance ( $r = 0.45$ ,  $t = 2.15$ ), which indicates that besides the parasite and the predator, temperature also plays an important role in regulating the SWF population. The monthly rainfall was generally low with the exception of December 1980 and 1981. There was a significant, negative correlation between the SWF and rainfall ( $r = -0.14$ ,  $t = 0.59$ ), indicating that rainfall may also have an effect in regulating the SWF population in lowland Honolulu.

#### Highland Honolulu

Fig. 3 shows a density of 55.7 SWF pupae when the study was initiated in May 1980. It increased to a peak of 1,015.3 pupae in July 1980 and gradually declined to 1.7 in February 1981. The population in the following months remained at a low level until June when there was a slight increase to 12.0 pupae. Subsequently, the population declined again and remained at a low level until the end of the study. A comparison of the two peaks of 1980 and 1981 revealed that the number of SWF pupae declined by 98.8%.

In highland Honolulu, where neither *N. amnicola* nor *E. ?haitiensis* had been released, *N. amnicola* was recovered in the fourth month of the study. However, little activity was recorded for this predator during 1980, and its density never exceeded 3 individuals. After February 1981, no *N. amnicola* was recorded. As shown in Table 1, there was a significant, positive correlation between the predator and the SWF ( $r = 0.19$ ,  $t = 0.75$ ).

In 1980, high host densities should have favored the actions of the predator. However, since there was no significant increase in predator activity, it indicates that *N. amnicola* may not be adapted to conditions in the higher elevations, as it was in the lower elevations. The variation in population densities of a single species in different habitats may be, among other variables, attributable to physical factors (Doutt and DeBach 1964).

*E. ?haitiensis* was first recovered in the sixth month of the study. Its density increased slowly and peaked at 16.7 pupae in December 1980. In the following months, density declined as the SWF population subsided. During 1981, there was an increase in parasite density in June along with a slight increase of the SWF population. In the following months, populations of both species remained at low levels. Table 1 shows that there was a significant, positive correlation between the parasite and the SWF ( $r = 0.61$ ,  $t = 2.78$ ). Hence, the effectiveness of *E. ?haitiensis* in low SWF population levels in 1981 indicates, as was observed in lowland Honolulu, that either a lower food requirement or a higher searching ability may lead to superior performance of the parasite over the predator (Doutt and DeBach 1964). Also, this may be an indication that *E. ?haitiensis* is adaptable to both highland and lowland conditions.

The average monthly temperatures generally followed a cyclic pattern similar to that observed in lowland Honolulu. Temperature reached a peak in September 1980 and 1981 and was lowest in February 1981. The SWF showed significant, positive correlation with fluctuations in temperature ( $r = 0.27$ ,  $t = 1.20$ ), which demonstrates, as in lowland Honolulu, that temperature plays an important role in regulating the SWF population.

Monthly rainfall fluctuated throughout the study. As shown in Table 1, there was no significant correlation between the SWF and rainfall ( $r = .08$ ,  $t = .34$ ).

In this study, none of the other two introduced coccinellids, *Delphastus pusillus* (LeConte), and *Nephaspis bicolor* Gordon, nor other parasites were ever recovered. However, there were other previously established predators recorded preying on the SWF. They were *Coelophora pupillata* (Swartz) and *Cryptolaemus montrouzieri*

**TABLE 1.** Summary of correlation and regression of the relationships between the spiraling whitefly (SWF), *Aleurodicus dispersus*, and its natural enemies, and between the SWF and climatic factors in lowland and highland Honolulu.

Y vs. X	r	d.f.	t value	Regression
<b>Lowland Honolulu</b>				
SWF × <i>N. amnicola</i>	0.58	18	3.03**	$y = 0.93 + .13x$
SWF × Other Predators	0.84	18	6.59**	$y = 0.91 + .02x$
SWF × <i>E. ?haitiensis</i>	0.12	14	0.42	$y = 3.12 + .09x$
SWF × Temperature	0.45	18	2.15**	$y = 5.10 + 0.1x$
SWF × Rainfall	-0.14	18	0.59**	$y = 2.68 - .03x$
<b>Highland Honolulu</b>				
SWF × <i>N. amnicola</i>	0.19	15	0.75**	$y = 1.09 + .01x$
SWF × Other Predators	0.95	18	12.58**	$y = 0.97 + .04x$
SWF × <i>E. ?haitiensis</i>	0.61	13	2.78**	$y = 1.22 + .18x$
SWF × Temperature	0.27	18	1.20**	$y = 4.89 + .00x$
SWF × Rainfall	0.08	18	0.34	$y = 4.02 + .01x$

\*\*Significant at  $P = 0.01$ **TABLE 2.** Number and percentage of predators recovered from lowland and highland Honolulu during May 1981 - December 1981.

Sites	No. of Predators (%)					Total
	<i>N. amnicola</i>	<i>C. montrouzieri</i>	<i>C. pupillata</i>	<i>A. obliqua</i>	<i>C. comanche</i>	
Lowland	260(95.2)	9(3.3)	0(0.0)	1(0.4)	3(1.1)	273(100.0)
Highland	18(26.5)	9(13.2)	1(1.5)	32(47.1)	8(11.8)	68(100.1)

Mulsant (Coleoptera: Coccinellidae), *Allograpta obliqua* (Say) (Diptera: Syrphidae), and *Chrysopa comanche* Banks (Neuroptera: Chrysopidae). Of these 4 predators, *A. obliqua* was the most abundant species.

There were significant positive correlations between the previously established predators and the SWF in both lowland and highland Honolulu ( $r = .95$ ,  $t = 12.59$ ;  $r = .84$ ,  $t = 6.59$ , respectively). They accounted for 73.6% of all predators recovered in highland Honolulu and only 4.8% of those recovered in lowland Honolulu (Table 2).

The lack of abundance of each individual species may be attributed to their general feeding habits, i.e., not showing a definite preference for the SWF. Mortality resulting from parasitization may have also contributed to the scarcity of these predators. In a separate study *C. pupillata* was reported parasitized by *Homalotylus* sp. (Encyrtidae) and *Tetrastichus coccinellae* Kurdjumov (Eulophidae), *C. comanche* by *Cheiloneurus* sp. (Encyrtidae) and *Brachycyrtus nawai* (Ashmead) (Ichneumonidae), and *A. obliqua* by *Ooencyrtus guamensis* Fullaway (Encyrtidae) (Hawaii Department



**FIGURE 4.** A. and C. Pre-release infestation of *Aleurodicus dispersus* on guava tree. Honolulu, Hawaii. Jun. 1979; B. and D. Post-release control of *A. dispersus* on the same tree. Jan. 1981.



of Agriculture, 1981). The previously established predators were most active in high SWF densities as evidenced in highland Honolulu in 1980; however, in low SWF densities activity was very minimal. This indicates that they may be ineffective in preventing upsurges of whitefly populations and are perhaps, incapable of suppressing the pest population below socio-economically tolerable levels by themselves. They may, however, play a role in reducing the rate of increase of the SWF at high population densities or in reducing its peak populations (DeBach 1951).

Although the abiotic factors, temperature and rainfall, may have played an important role in regulating the SWF population, this study indicates that the introduced natural enemies have been very effective in reducing the SWF population. *N. amnicola* was more effective in high SWF population in lowland Honolulu and *E. ?haitiensis* was more effective in low SWF populations in both highland and lowland Honolulu. The SWF is now under good biological control in most areas on the islands of Oahu, Kauai, Maui, Hawaii, Lanai and Molokai.

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